Assessing the Lifetime Performance of the Lightning Imaging Sensor (LIS): Implications for the Geostationary Lightning Mapper (GLM)

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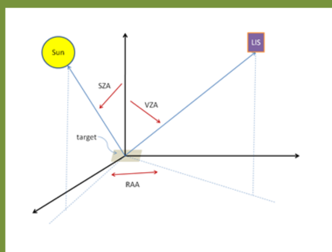
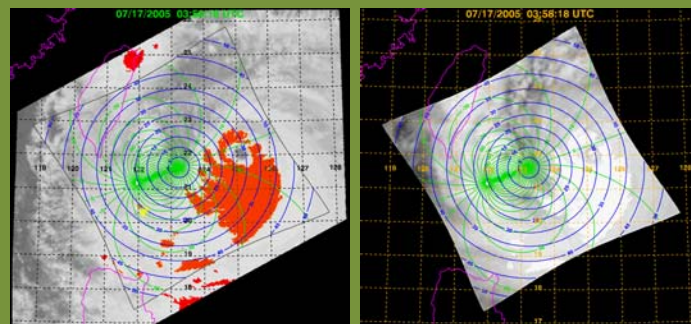
Motivation: Analyze the performance of the Lightning Imaging Sensor (LIS) over its 13 years in orbit and examine implications for the Geostationary Lightning Mapper (GLM) .

Deep Convective Cloud Technique: Deep Convective Clouds (DCC) are used as stable targets to examine the radiance of LIS background (BG) pixels over its 13 year period in orbit. DCC are identified as VIRS (Visible and Infrared Sensor) 10.8 µm channel pixels having brightness temperatures (T_b) colder than 205K . LIS background (BG) pixels co-located with the DCC pixels are used in the analysis. The LIS and VIRS are both onboard the Tropical Rainfall Measuring Mission (TRMM) satellite).



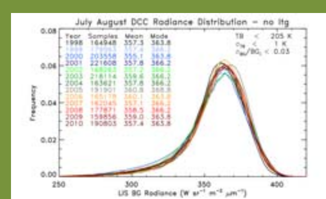
Criteria for LIS BG pixels used:
1) 10.8 µm T_b < 205K
2) Solar Zenith Angel (SZA) < 40°
3) Viewing Zenith Angle (VZA) < 40°
4) Relative Azimuth Angle (RAA) > 10° and < 170°
5) Ratio of standard deviation of pixel radiance and its 8 surrounding pixel radiances divided by the pixel radiance < 0.02



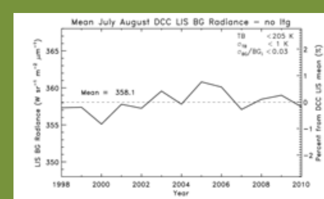
Example of VIRS IR image (left) and LIS BG image (right) for Super Typhoon Haitang
The left panel also shows the locations with VIRS 10.8 channel $T°_b$ with pixels > 205K in red. The small orange boxes are the LIS BG pixels sizes associated with the cold VIRS pixels. Locations of lightning events detected by LIS are also shown (yellow +). In the right panel, LIS flashes are denoted by yellow '+'. Both panels show contours of RAA (green) and VZA (blue).

The DCC analysis was conducted on LIS BG data for each July and August from 1998 – 2010. The data were analyzed in a two month period to ensure sampling. Results shown at right illustrate that the frequency distribution was very uniform throughout the period. In addition, the mean radiance for each year deviated 2% at most from the yearly mean.

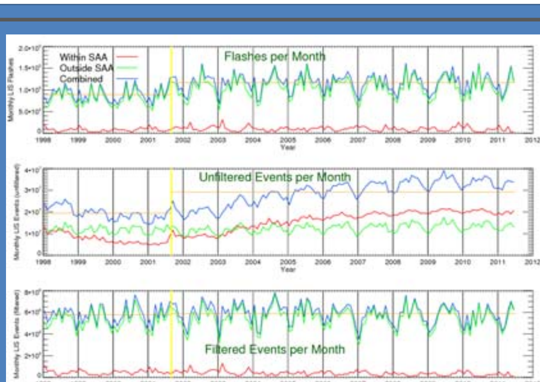
Conclusions:
1) The DCC analysis of the LIS indicates no discernible degradation of instrument performance over its lifetime in orbit.
2) Due to its similar design, the GLM should also experience little performance degradation.
3) The DCC technique can be used to monitor GLM instrument performance once in orbit.



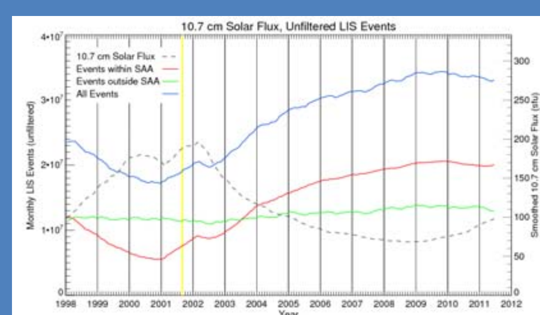
Frequency distribution of DCC LIS BG radiances for each year (1998-2010). The mean , median DCC radiance and the number of DCC LIS BG pixels for each July and August are also shown.



The mean yearly DCC LIS BG radiance for July and August. The solid horizontal line is the mean yearly value. The scale on the right indicates the yearly percentage difference from the mean.



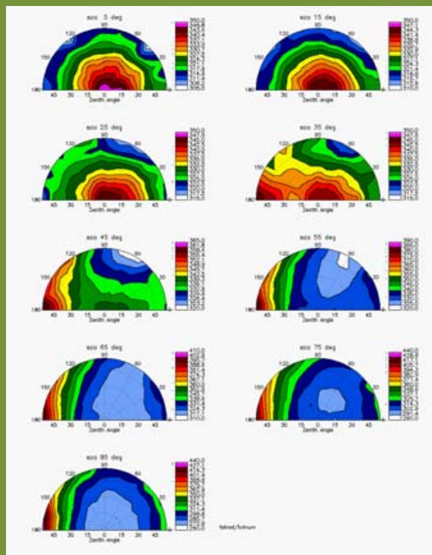
Monthly time series of LIS flashes (top), events before filtering (middle), and after filtering (bottom). Blue indicates all observations, red are observations within the South Atlantic Anomaly (SAA), and green for observations outside the SAA. The yellow vertical line (August 2001) indicates the when the orbit was boosted from 350 km to 403 km. The orange lines are the mean of all monthly observations for pre- and post- boost periods



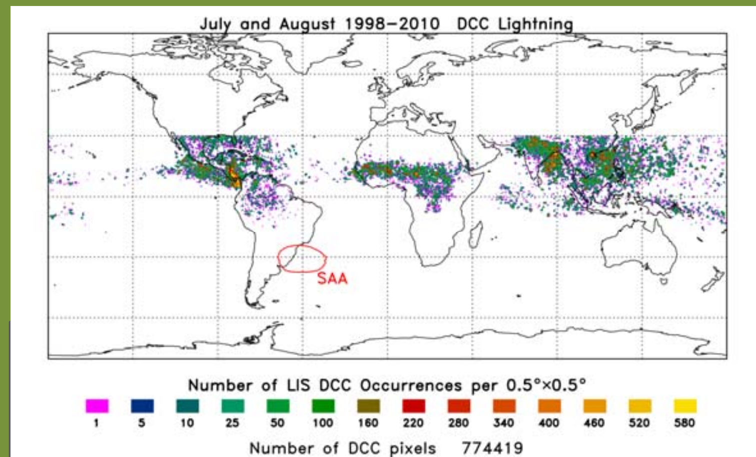
Time series of monthly LIS filtered and unfiltered events within (red) and outside (green) the SAA., and the combined values (green). The black line is the monthly 10.7 cm solar flux (sfu). The yellow vertical line indicates the TRMM orbit boost.

The number of flashes observed per month increased after the orbit boost, however, there is no discernible trend in monthly flashes prior to or after the boost. The unfiltered events show a distinct uptrend after the boost. Numerous false LIS events occur over the South Atlantic Anomaly (SAA) due to geomagnetically trapped ionized particles impacting the LIS sensor. The monthly unfiltered events were then partitioned as to being within or outside the SAA region. The trend in unfiltered events is seen to be due to false events occurring within the SAA and is inversely related to the 10.7 cm solar flux.

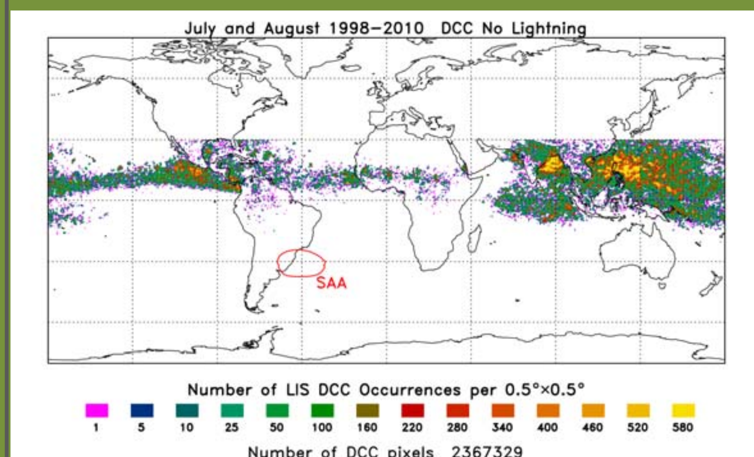
Conclusions:
1) LIS flash and event detection (after filtering) are stable over the period. This indicates GLM simulation activities using LIS data can be done using data from different years.
2) Validates the the robustness of the LIS filtering and clustering algorithms.
3) The LIS unfiltered events is inversely related to the 10.7 solar flux.



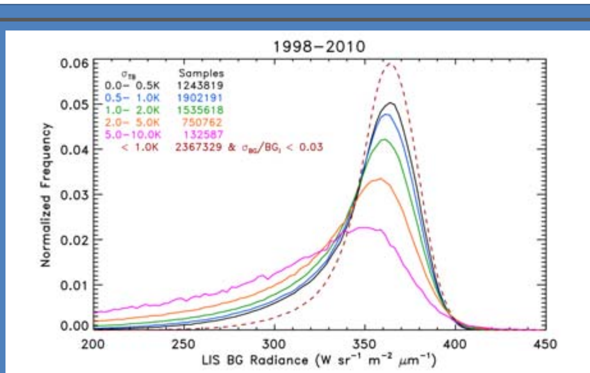
Distribution of LIS background radiance of deep convective clouds. This distribution is being used to derive an angular distribution model (ADM) to correct for anisotropy is the reflected radiance.



Location of LIS observed deep convective clouds for LIS BG pixels that had lightning occurring within 50 km. There is a greater percentage of LIS BG pixels over land than over ocean when compared to the no lightinng case.



Location of LIS observed deep convective clouds for LIS BG pixels that had no lightning occurring within 50 km. These occur mainly over the oceans.



Distribution of LIS BG radiance for DCCs. These figures show the effect of using various 11 µm brightness temperature thresholds in defining DCC. The LIS DCC radiance distribution is more better defined and brighter for clouds with lightning located within 25 km of them. This could be because these clouds are actually brighter or could be a result of contamination by the lightning. The brightness of LIS DCC pixels over land are brighter than those over the oceans. This is probably due to the time (around solar noon) that the DCCs were observed. This is when convection over the land is increasing. The diurnal cycle of convection over the oceans is less pronounced.